Special Instruction

Troubleshooting root cause of cracked flywheel housings or loose / broken flywheel housing bolts

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SEHS79140001

Troubleshooting Root cause of Flywheel Housing/bolt failures

SMCS - 1000

Introduction

The purpose of this instruction is to give a simple procedure for the diagnosis of flywheel housing cracks and/or flywheel housing loose/broken bolt failures on primarily truck engine applications. Experience has shown that these types of failures are usually not due to a defect in engine or flywheel material and/or workmanship, but are caused by one of the following:

1. Engine mount defects due to misalignment or improper design.
2. Truck being used in application other than the original design intent.
3. Misalignment or out-of-balance of engine driven equipment.
4. Insufficient rear support of transmission overhung weight.

The above defects contribute to flywheel/bolt failures that may appear to the operator to be caused entirely by the engine. This troubleshooting procedure has been designed to diagnose the true source of the failures with a minimum expenditure of time and material.

Does a vibration exist?

i. If yes, please consult Special Instruction SEHS7914, Titled "Troubleshooting Engine Vibration in Vehicular Equipment". Complete the Vibration Questionaire.
   a. If after completion of the questionnaire, it is determined that the vibration occurs only when the vehicle is in motion or only when the engine is under load, then **the engine is not the cause of the vibration.** At this point, the engine vibration troubleshooting is complete. Further investigation to determine which chassis component(s) are the root cause will be at the customer's expense. The customer has the option to take the unit to his OEM dealer for further investigation.
   b. If it is determined the engine is the source of the vibration problem, the remainder of SEHS7914 should be followed up to/and including conducting an isolated engine vibration test.

ii. If no, further investigation to determine which chassis components are the root cause will be at the customer's expense. The customer has the option to take the unit to his OEM dealer for further investigation.

NOTE: If the failure is an early hour failure, there is a possibility of material and/or workmanship defect. Please consult your Caterpillar Service Representative.

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not have a vibration problem.

(C) Instructions For Table 2

For each probe location in Table 1, determine the engine speed that produced the largest filter-out displacement. Re-measure the filter-out displacement at this engine speed, and the filter-in displacements for 1/2, 1st, 2nd, 3rd and 4th order vibrations. Do this for each of the six probe locations. Use the following formula to determine the order of vibration.

If another order of vibration is found to have significant filter-in displacement amplitudes, record this displacement amplitude and order of vibration in the column marked "Other".
NOTE: For a more detailed analysis, it may be necessary to obtain additional filter-in data. When measuring filter-in displacement amplitudes with a vibration meter, it is helpful to mentally calculate the frequency corresponding to each order of vibration. For example, if the engine speed is 1200 rpm, the anticipated frequency values will be 600 cpm for 1/2order, 1200 cpm for 1st order, 2400 cpm for 2nd order, 3600 cpm for 3rd order, etc. However, do not ignore large displacements that may occur at some other order. For example, if an unbalanced cooling fan operates at 0.7 engine speed, then at the same engine speed of 1200 rpm there will be a 0.7 order vibration measured at 840 cpm.

(D) Interpretation Of Data

Because of the large variety of engine configurations and mounting systems, it is not possible to establish allowable levels for in-chassis vibration. However, two important results can be determined from the data recorded in Table 1 and Table 2.

1. "Resonant" or "Non-Resonant" - Look at the columns of data in Table 1 (probe location vs engine speed). If the displacement amplitude values are similar for most engine speeds, but peak at specific engine speeds, resonance exists. If the displacement amplitude values are similar for all

engine speeds, this is considered as a non-resonant condition. Resonance may occur at one or more of the probe locations.

2. "Significant Order of Vibration" - Look at the rows of data in Table 2 (overall displacement and filter-in displacement). The "order" corresponding to the filter-in displacement that is significant relative to the overall (filter-out) displacement is considered to be the significant order of vibration. Determine the "significant" order of vibration for each probe location listed in Table 2.

These results are used to determine the cause(s) of vibration as shown in the following summary.

(E) Additional Tests

After the initial in-chassis test data has been taken and interpreted, if one or more sources of vibration are discovered, then all defective components should be repaired and all vibration measurements requested in Table 1 and Table 2 should be repeated. This repair and re-measure procedure may have to be repeated several times to eliminate all possible sources of vibration.

If no defective engine components are found and if the vibration is diagnosed as a resonance condition, then loosen the bolts in all engine mounts and repeat the measurements. Operating the vehicle with loose engine mounts is not an acceptable solution to the vibration problem, but doing this will verify whether or not the engine mounts are misaligned. If the engine mounts are correctly aligned, the mounting bolts will slip freely through the mounts. If necessary, use shims or relocate the mounts to get the correct alignment.

After all possibilities suggested above have been investigated, perform the isolated engine vibration test if the engine is still suspected of being out of specification.

Engine Vibration Data Sheet For Vehicular Equipment ·

Record in Table 1 the filter-out displacement for each engine speed and probe location. Circle the units used: mils or microns. If significant displacement amplitudes occur at engine speeds between those listed, mark out rpm values shown and enter new rpm values in adjacent column.

Remeasure the largest value for each probe location and record this information in Table 2 for both the filter-out and filter-in displacements.

Performing An Isolated Engine Vibration Test

This test will determine if the engine vibration is within Caterpillar's allowable level. For the test to be valid, all flywheel driven equipment must be removed and the engine suspended or mounted on very soft isolator mounts. It is acceptable to suspend the engine with a chain hoist. The engine can be suspended within the chassis, but the clutch, transmission and engine mounts must be removed so there are no major connections to the chassis. It is not necessary to disconnect the fuel lines, radiator hoses, wiring or other minor connections.

The data sheet for the Isolated Engine Vibration Test is shown on page 12 of this instruction. Additional data sheets for the In-Chassis Vibration Test and the Isolated Engine Vibration Test are available in pads of 50 sheets by ordering Special Instruction Form SEHS7915.

If a 3408 Engine is to be tested for vibration with the flywheel driven equipment removed, weight must be attached to the face of the flywheel at the 9:30 o'clock position (as viewed from the rear of the engine with No.1 cylinder at top center) to correct for normal out-of-balance of the crankshaft/flywheel. The amount of weight attached multiplied by the distance of the weight from the centerline of the crankshaft equals the correction factor shown below.

1. Remove all bolts from the clutch bolt circle.
2. Make sure No.1 cylinder is at top center position.
3. Install two 7/16"-14 bolts one inch long (without washers) in the clutch bolt circle, one at the 9 o'clock position and the other at the 10 o'clock position as viewed from the rear of the engine.

(A) Engine Speed

Vibration levels are not expected to vary significantly with engine speed for this test. It is recommended that the test be run at either the rated speed or an objectionable speed as determined from Table 2 of the In-Chassis Vibration Test. Record engine speed in the space provided on data sheet.

(B) Probe Locations

Probe locations are the same as the five locations described in the In-Chassis Vibration Test. For this test however, it is not necessary to measure vibration in the cab.

(C) Instructions For Table 3

Measure and record displacement amplitudes for all five probe locations as requested in Table 3. Overall (filter-out) displacement amplitudes and filter-in displacement amplitudes are required. For each order, compute and record the corresponding frequency. For example, if the engine speed is 1200 rpm, the frequencies are 600 cpm for 0.5 order, 1200 cpm for 1st order, 2400 cpm for 2nd order, 3600 cpm for 3rd order, etc.

(D) Allowable Vibration Levels

On the chart Allowable Vibration Levels, plot the filter-in displacement amplitudes for all five probe locations for each frequency. Do not plot if the displacement amplitudes are less than 1 mil. Do not plot overall (filter-out) vibration data.

(E) Interpretation Of Results

If all data points fall below the line, then the engine complies with Caterpillar's vibration limits. If the engine exceeds the vibration limits, refer to the table on pages 8 and 9 to determine the cause of the vibration. Consult your Service Engineering Product Analyst for advice on repair.
Isolated Engine Vibration Test

Use the graph below to plot all filter-in displacement data. The curve shown on the graph below is the allowable vibration level for an isolated Caterpillar engine.

Example Problem

(A) History

A customer with a 3406 Engine in an International conventional cab truck complained about a vibration problem. The driver reported that the vibration was not present until after recent service work when the engine water pump was replaced. Naturally, the water pump was suspected as being the source of vibration; but close examination of the water pump revealed nothing abnormal. The procedure and test data sheets from this instruction were used to diagnose the vibration problem.

(B) Filling Out Engine Vibration Questionnaire

The first step in diagnosing the vibration problem is to fill out the engine vibration questionnaire. The completed questionnaire is shown below. Notice that a bolt in the engine front mount was found to be loose. However, tightening this bolt did not eliminate the vibration. The questionnaire also shows that the vibration was most noticeable at 1200 rpm, which suggests the vibration is resonant related. Because the vibration was present with the vehicle stationary and no load on the engine (as shown by the answer to question 10), an in-chassis vibration test was performed using an IRD Model 320 Vibration Meter.
Engine Vibration Questionnaire For Vehicular Equipment

(C) Measurement And Interpretation Of In-Chassis Vibration Data

Data recorded in Table 1 of the In-Chassis Vibration Test below shows the following information:

1. The largest displacement amplitude measured 17.0 mils at Front Horizontal at 1400 rpm.
2. There was a resonance at both Front and Rear Horizontal at 1400 rpm.
3. There was a resonance at both Front and Rear Vertical at 1200 rpm.
4. The largest displacement amplitude measured in the cab was 4.2 mils at 1200 rpm. This correlates with the reply to question 7 on the questionnaire which indicates that the vibration was most noticeable at 1200 rpm.

Remeasure the largest value for each probe location and record this information in Table 2 for both the filter-out and filter-in displacement.

The engine speeds and probe locations corresponding to the overall displacement amplitudes circled in Table 1 were selected for measuring filter-in displacement amplitudes. The filter-in displacement amplitudes recorded in Table 2 show the following:

1. The "significant order of vibration" was observed to be 1st order for all engine probe locations.
2. One half (1/2) order vibration was detected in both Front and Rear Horizontal directions, although displacement amplitudes are not significant compared to 1st order vibration.
3. Overall displacement amplitudes remeasured in Table 2 did not exactly repeat those originally measured in Table 1, but the measurements were within 1 mil of each other. This characteristic is typical of vibration data.
4. The 3rd order displacement amplitudes shown indicate the firing frequency of a six cylinder engine.

In summary, the results shown in Tables 1 and 2 indicate that there was a horizontal mount resonance at 1400 rpm and a vertical mount resonance at 1200 rpm; both resonances occuring at a frequency corresponding to 1st order vibration. The displacement amplitude was greatest at the front of the engine.

The table on page 8 indicates that a 1st order vibration is caused by an out-of-balance component that rotates at crankshaft speed. Upon close examination of the engine's front pulley and damper, it was discovered that two of the bolts were missing that fasten the pulley and damper to the crankshaft. These bolts were replaced and the in-chassis vibration test was repeated.

(D) Repeat In-Chassis Vibration Test

After the two missing bolts were replaced, the in-chassis vibration measurements were again taken and recorded in Tables 1 and 2 of a new data sheet. The following results were obtained:

1. The displacement amplitude that previously measured 17 to 18 mils at Front Horizontal at 1400 rpm was now reduced to 1.9 mils.
2. The cab vibration at 1200 rpm was reduced from 4.2 mils to 2.2 mils. The customer considered this to be an acceptable level of vibration.
3. The largest displacement amplitudes measured were 3.2 and 3.6 mils at Front and Rear Horizontal at 700 rpm. These vibrations were primarily 3rd order (firing frequency).

This vibration problem was solved by replacing the missing bolts in the pulley/damper. To verify that the engine complied with Caterpillar's allowable vibration levels, an isolated engine test was performed.

Engine Vibration Data Sheet For Vehicular Equipment

Record in Table 1 the filter-out displacement for each engine speed and probe location. Circle the units used: mils or microns. If significant displacement amplitudes occur at engine speeds between those listed, mark out rpm values shown and enter new rpm values in adjacent column.

Remeasure the largest value for each probe location and record this information in Table 2 for both the filter-out and filter-in displacements.

(E) Perform Isolated Engine Vibration Test

After the bolts were installed in the pulley/damper and the in-chassis vibration test was repeated, the vehicle was prepared for an isolated engine test. This was done by suspending the engine, in place in the vehicle, with a chain hoist. The engine mounts, transmission, and fan were removed. The exhaust pipe, fuel line, throttle linkage and wiring were left in place. There was no mechanical connection between the engine and the chassis except for the exhaust pipe and fuel system linkage.

The isolated engine vibration test was performed with the engine operating at 2100 rpm (rated speed). For each of the five probe locations, the displacement amplitudes and frequencies were measured and recorded in Table 3 of the data sheet as shown below. All filter-in displacement data with displacement amplitudes greater than 1 mil have been plotted on the Allowable

Vibration Level graph. All data points fall below the allowable curve; therefore, the engine complies with Caterpillar's allowable vibration levels.

Use the graph below to plot all filter-in displacement data. The curve shown on the graph below is the allowable vibration level for an isolated Caterpillar engine.